Seismos G.M.B.H., Hannover.
Exploration of rock strata.

PUBLICATIONS OF THE SEISMOS COMPANY.

I.

Exploration of Rock Strata and Mineral Deposits by the Seismic Method.

[illegible] ANN[illegible] ERMANY
[illegible] EISMO[illegible] B.H.
[illegible] 22

The seismic method of Dr. Mintrop uses artificially generated elastic waves for the determination of depth, character and thickness of rock strata and mineral deposits.

The waves are generated at the surface by means of detonations or falling devices. They are also recorded at the surface by means of light portable seismographs, no bore holes or prospecting shafts being necessary.

Fig. 1. Excitation, propagation and seismographical recording of elastic waves.

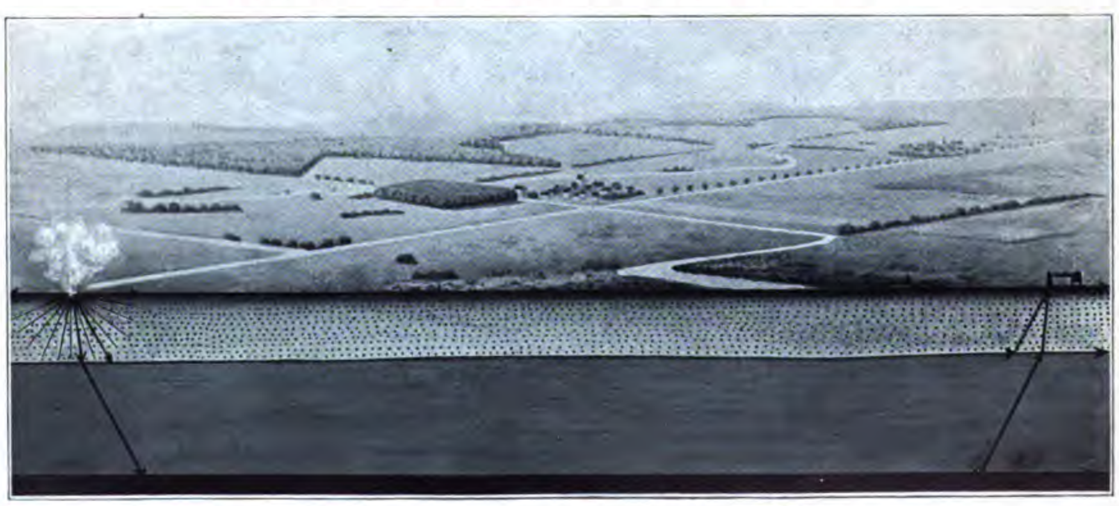

Fig. 2. Process of seismographic registration of a detonation.

The details of a registration may be seen in Fig. 2. To the right, a detonation occurs, the elastic waves of which are photographically recorded by a seismic apparatus set up at the left. Jn case of very small depths, the elastic oscillations may be produced by means of a falling device, which is also light and portable.

From the seismographical records of several detonations made successively at different distances from the seismograph, the speeds of the elastic waves in the various depths below the surface as well as the depths themselves result, according to known methods of seismology, especially Wiechert's theory of earthquake waves. Definite speeds are found to occur in the different rocks, depending on their elasticity and density. From observations made on the surface the method thus allows to determine the depth, thickness and nature of rock strata and mineral deposits, as well as their striking and dipping.

Fig. 3. The seismic apparatus changing location.

The method is primarily qualified for the determination of the structural conditions in areas which are not yet explored geologically. It furnishes contour lines on hard rocks which are overlain by a less hard overburden, and gives information about the petrographic condition of the various rock strata. It is further possible to determine depth and thickness as well as strike and dip of several superposed formations. In many cases the running and the amount of faults can also be determined. Another field of application of the method is the investigation of the construction ground, especially before the sinking of shafts and before the path of a projected tunnel or canal is definitely decided on.

The method is a valuable aid to practical geology and mining. It offers the following advantages:

1. Quick information on structural conditions.

   Calculation and interpretation of the results are made at once in the field. Under average conditions, it is possible to determine a geological profile within a day. In simple cases several profiles are determined during one day, while the seismic investigation of large areas, extending over many square kilometres, takes only a few days or a few weeks.

2. Low costs. The use of the method requires only a fraction of the cost of a single bore hole, while the structural conditions of a considerable area are elucidated.

Drilling operators will find to their advantage that the application of the method before the actual drilling will furnish the prospective depth of the well and the character of the rocks to be encountered, in such a way that the type of derrick to be selected and the particular drilling procedure can be predetermined.

In the following, investigations carried out by the Seismos Company will be explained. The company, which was founded in 1921, applies the method for all those interested in mining and geological exploration.

Fig. 4. Seismic field procedure.

Specimen cases of application.

The method was repeatedly applied in Northern Germany for the exploration of salt domes. These investigations succeed in determining the edges, the depth and the extension of the dome.

A simple specimen case of the application of the method is shown in the figures 5 and 6. The sheet "Winsen an der Aller" of the map 1:25000 of the Prussian Geological

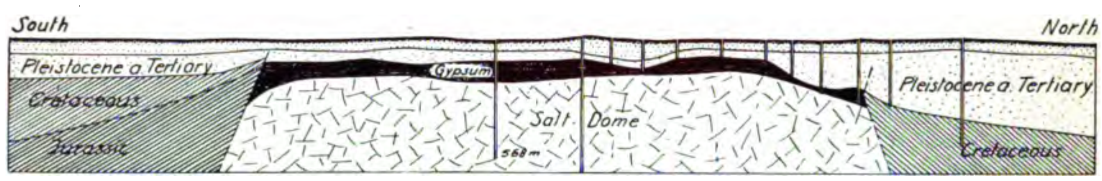

Fig. 5. Profile of the salt dome Hambuehren-Steinfoerde-Wietze.

Survey, worked out by H. Monke and J. Stoller, shows the well known salt dome of Hambuehren-Steinfoerde-Wietze, which strikes in Hercynian direction. In its southeastern and northwestern part this dome was determined by many wells, here the running of the

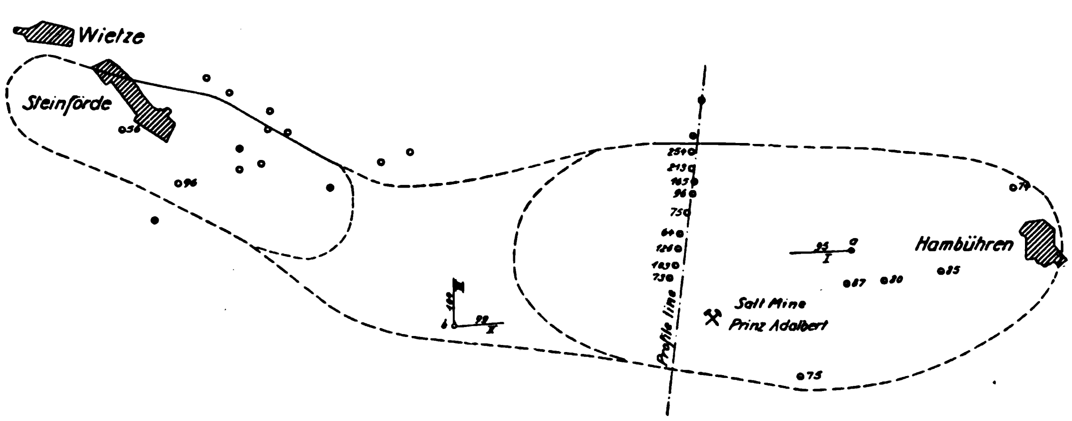

Fig. 6. Ground plan of the salt dome Hambuehren-Steinfoerde-Wietze.

outline is — at least in part — accurately known. However, at the time of the publication of the map, the question was left open whether a connection existed between both parts, or whether this was a case of two separate domes. According to the

geological map and the explanations by Harbort, E. Seidl and J. Stoller attached thereto, both possibilities are admitted, on account of the total lack of bore holes. The two possible cases are indicated by (1) a connection of the flanks by dashes, and (2) by closing the contour line around each one of the two summits (dashed line). In order to find out whether such a connection between the two domes existed, the Seismos Company, in cooperation with the Salt Mine Prinz Adalbert, shot the line I, which runs from point a (see fig. 6) in the direction of the strike towards the west. This line is situated on the eastern part of the salt dome, which part is well known because many wells were drilled there. A depth of 95 metres resulted, while the nearest bore hole shows a depth of 87 metres. The application of the method therefore gives a result which agrees well with practical data.

On the same day, lines II and III, starting from point b, were shot. Point b is situated 4 kilometres west of line I, and therefore, beyond the projected western boundary line of the eastern part of the dome. The depth was found to be 99 metres in line II and 104 metres in line III.

It can therefore be concluded: The assumed western edge of the eastern part of the dome does not exist. The saltdome extends in uniform depth underneath the overburden towards the west. It took the seismic method only one day to arrive at this conclusion.

In the known northwestern part of the saltdome near Wietze detailed investigations were made, the results of which are in good agreement with the borings located in that district.

The correct working and the applicability of the method could be proven in a number of specimen cases in which the seismic predictions were substantiated by actual drilling.

Comprehensive investigations were made for the Deutsche Erdoel-Aktiengesellschaft, at first for the purpose of testing the method on the Wietze saltdome and then for the outlining of a new saltdome, the extension of which was so far unknown. Several years ago another company had endeavoured to outline this dome by means of numerous wells, most of which, however, gave but insufficient information. Within a few days, the investigation of the Seismos Company determined the depth and the extension of this dome. After one well had confirmed the results, an additional area, comprising several square kilometres, was also investigated.

Apart from the finding of the depth and the extension of a saltdome, there also results the determination of the character of the surrounding formations. —

Another extensive investigation was made for a certain oil company which had selected the site for a well upon the advice of a consultant. This particular well found the Senonian formation in undisturbed position underneath the Tertiary, at a depth of 514 metres, and was still in it at a depth of 1000 metres. The hope to find oil had been disappointed. Now, oil occurs in Northern Germany exclusively around the edges of saltdomes. After the sinking of the well, the company applied to the Seismos Company, asking the latter to determine whether or not a saltdome existed in the part of its concession adjoining the well.

The field work started with the shooting of a line near the well. The records here obtained allowed a good check on the method by comparison with the well log. The observations in a number of lines which covered the whole area (of about 30 squ. kilometres) resulted, without exception, in depths between 500 and 600 metres. Furthermore, the same uniform formation was found at these depths. It could therefore be concluded that the Senonian occurs in undisturbed position underneath the Tertiary, as shown in

the running of the section of Fig. 7 toward the north. A subterranean uplift does not exist in this area. In view of these results the oil company decided not to drill a new well.

Fig. 7. Seismic section determined in connection with well.

The investigations of the Seismos Company in this area (30 squ. km) were made within a few weeks, inclusive of the interpretation of the results and the final report. The costs of the seismic method amounted to less than one tenth of the costs of a single bore hole. Therefore, a considerable economy in time and money results when this method is applied.

The application of the method in salt and oil districts is not limited to the determination of pronounced anticlines of the type of the North German, or other, salt domes, but the method can also determine gentle uplifts or depressions of the deep underground. Under certain favorable conditions, oil-producing formations can be determined, and information on the petrographic condition of the different rocks can also be obtained.

A detailed investigation of the overlayers of the carboniferous formation was made in extended areas and down to considerable depth, in the coal mines of Friedrich Heinrich, Rheinstahl and Phoenix, on the Lower Rhine. Fig. 8 contains a section running through the Camp II well, in the Friedrich Heinrich block. This well penetrated Pleistocene and Tertiary formations and found Triassic sandstone (Buntsandstein) lying almost horizontally in a depth of 252 metres. It is supposed that west of this well the Sonsbeck-Camp fault occurs, according to the logs of wells Camp IV and V which are located farther north.

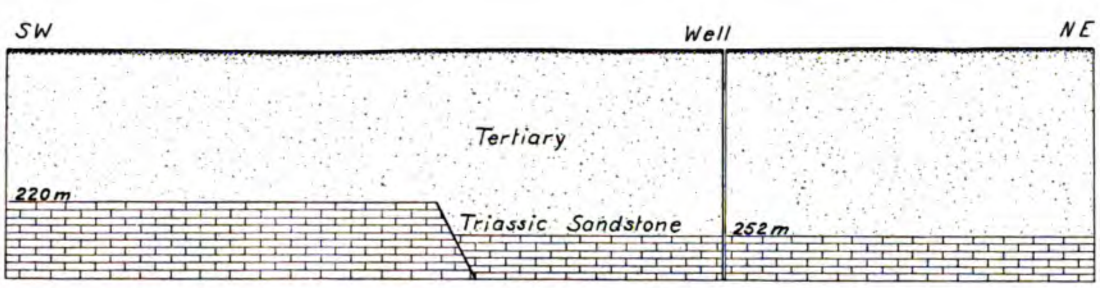

Fig. 8. Section with a seismically determined fault.

Seismic observations in a section running through well Camp II were in good agreement with the well log. In contrast to this, a depth of only 220 metres was found in line observations 800 metres southwest of this well. As an almost horizontal running of the boundary face between Tertiary and Triassic sandstone was found in both cases, it must be concluded that a fault exists between the well and the seismically determined section.

This fault displaces the overburden by about 30 metres. The investigations made in the remaining blocks gave information about the existence of faults and on their extent. They allowed to determine the outcrop of these faults in the overburden. They also made possible conclusions regarding the type of deposition and the petrographic condition of the deep formations. It can be safely assumed, for instance, that the deeper part of the Sonsbeck-Camp fault contains the Triassic sandstone in the same compact form in which it was found in the log of the Camp II well. As against this, other districts were found in the investigated area, where the Triassic sandstone (which is found between the Tertiary and the Permian) has been deprived of its cement due to strong leaching and, therefore, is now very brittle. Such districts, which, in some cases, rendered the sinking of shafts very difficult, are always limited by faults. Where Permian occurs underneath the Triassic sandstone, the transition between these formations could be determined at depths of more than 500 metres. —

Detailed investigations of the petrographic differences in the Pleistocene and Tertiary and in the still deeper carboniferous formations were made in the Central German Coal District near Ploetz, in the Halle region. Fig. 9 shows a section from which the sequence of formations may be taken. The seismic determinations in a number of sections determined thickness, striking and dipping of the overburden as well as of the different beds in the carboniferous formation. These results were in good agreement with known wells. Furthermore, variations in the character of the overburden, such as gravelly, loamy sandy or purely sandy composition could be determined.

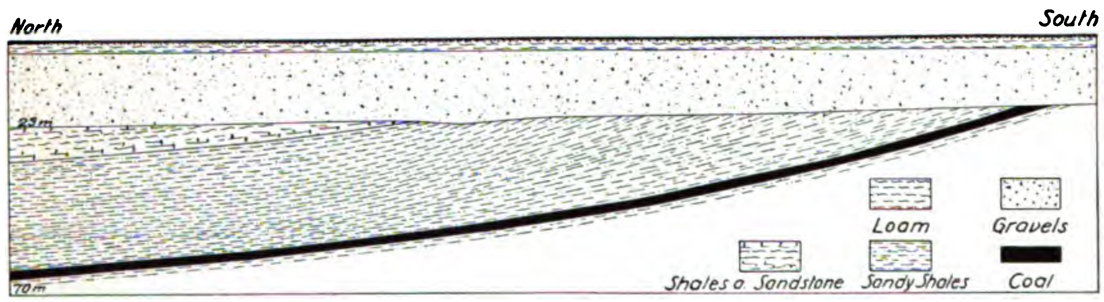

Fig. 9. Seismically determined section through coal district near Ploetz.

Investigations in the Central German Brown Coal District proved that the method can be used for the finding of coal and for the determination of the depth and of the lateral boundaries of synclines. Also, the differences existing in the overburden, f. i. between loam, loess and sand, can be determined, as well as the condition of the coal, whether it is solid or worked-up. —

In the following example the quartzite deposits of the Westerwald will be treated. Fig. 10 shows a section, in which a quartzite bank occurs underneath a 12 metres overburden of loam, bolus and variegated clays.

Deposits of quartzite were investigated in the Herschbach and Hachenburg districts for the Rheinische Stahlwerke and Phoenix. Fig. 11 shows the plan of a block which was investigated with 15 sections. Those located in the left and center part of the block contain quartzite in their entire extension. In the right part of the block quartzite is

lacking. The figures appended to the various lines indicate the thickness of the overburden, which varies from 5 to 12 metres. A comparison with the depth of the prospecting shafts shows that very good agreement exists between the seismic determinations and the logs and exposures. —

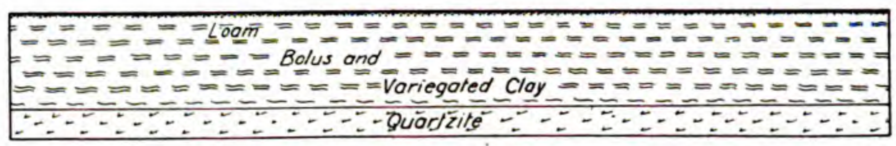

Fig. 10. Section through quartzite deposits, in the Westerwald.

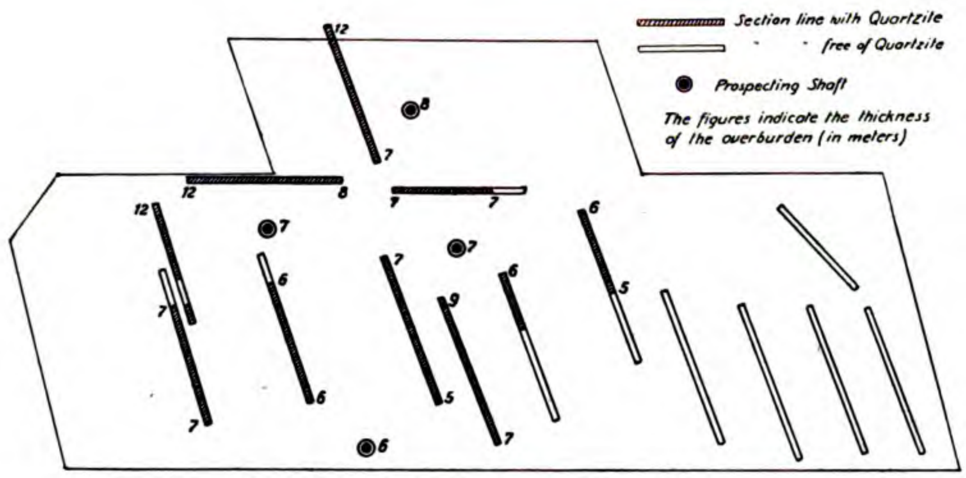

Fig. 11. Plan of a seismically investigated quartzite field.

Detailed measurements of the depth of older formations under younger overburden were made in the limonite region of the Lahn River, within the district of the Schaumburg mine of the Phoenix A. G. As a rule, the limonite deposits occurring in the Middle Devonian "Schalstein" outcrop jointly with the "Schalstein". In many places, however, very thick Tertiary overburden occurs, which consists of coarse quartz gravels interstratified with sand. Fig. 12 shows part of sheet "Schaumburg" of the geological map 1 : 25 000.

The Wilhelm shaft of the Schaumburg mine, when brought down, went through an unexpected great thickness of the overburden (63 metres). For this reason, the sinking of the shaft had been both difficult and expensive. A preliminary investigation of the overburden by drilling, to determine its thickness and composition, is hardly practicable, on account of the extended occurrence of gravel breccias which are solidly cemented together. Seismic surveys of such areas are much simpler and cheaper, and require considerably less time than borings.

Figures 14 and 15 show the results of the seismic determinations. Fig. 13 is a topographic plan of the surroundings of the shaft, which shows that the surface of the district is gently sloping. In contrast to this, the plan of depth contour lines in Fig. 14 shows

much more pronounced depth differences for the boundary face between overburden and "Schalstein". The negative figures appended to the curves refer to the level of the bore hole of the Wilhelm shaft, which is also the point of reference for the contours of Fig. 13. It will be seen that the shaft is located in a pronounced Tertiary basin. The section of Fig. 15 allows still better to recognize this. Such basins with funnelshaped depressions occur quite frequently in this broken country. The geologic map only shows them in the plan of the surface but not in sections, because the borings necessary for the plotting of sections are lacking. The seismic method, therefore, is capable of supplementing the geologic map in points which are of essential importance for mining and other interests. —

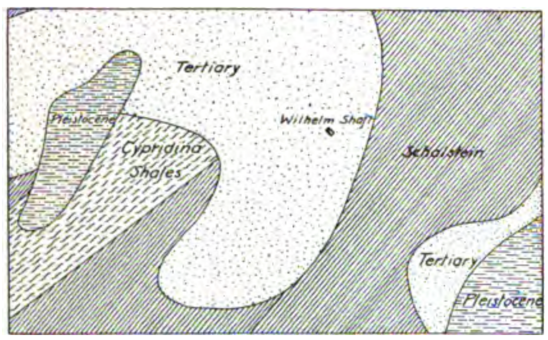

Fig. 12. Part of sheet "Schaumburg" of the geologic map.

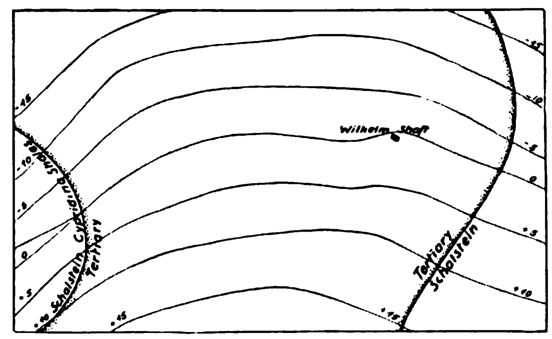

Fig. 13. Contour lines on the surface.

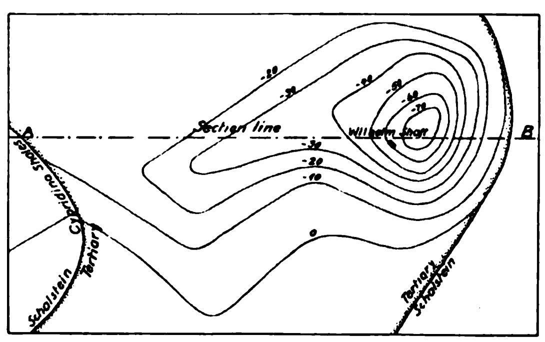

Fig. 14. Depth contours of the "Schalstein" seismically determined.

Fig. 15. Section across Tertiary basin, seismically determined.

For the Erzstudiengesellschaft in Dortmund, and other parties, the extension, depth and thickness of ore-deposits was determined in the Salzgitter Hills. In connection with this survey, investigations were made in regard to the structure of the west and east flank of the elevated ridge near Salzgitter and Gross-Doehren. Figures 16 and 17 show sections through the wells Johannes and Baerenkopf which are located on the west flank of the ridge in a distance of 3 km from one another (measured along the strike). The log of the Johannes well (subsequently referred to as well No. 1) shows 19 metres of Pleistocene overburden, and then Emscher Marl down to a depth of 270 metres, while the Baerenkopf well (subsequently referred to as well Nr. 2), which is located 50 metres higher on the surface, encountered the Turonian in a depth of 200 metres. The Turonian is normally following underneath the Emscher Marl.

The seismic determinations made at well Nr. 1 resulted in a depth which agrees with the well log, it was further found that the formations are dipping to the SW, with an angle of 24°. In the longitudinal section of Fig. 17, the boundary face between Emscher

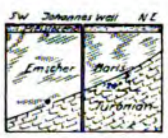

Fig. 16. Cross section.

Fig. 17. Longitudinal section at west flank of Salzgitter Hills.

Marl and Turonian runs horizontally, until a point about 2 kilometres distant from well Nr. 1 is reached, from where on it rises toward well Nr. 2 at an angle of 4 degrees with the horizon.

Comparing these seismic observations (which agree with the borings) with the geological projections, it will be seen that the cross section J-K of the geological map (sheet Salzgitter) which is located 1900 metres southeast of the Johannes well, already shows the Turonian at a depth of 190 metres, while the longitudinal section of Figure 17 does not show this formation until a depth of 270 metres is reached.

The seismic method, therefore, is capable of aiding geologic projections in an efficient way.

This will be elucidated even more in the sections given by Figures 18, 19 and 20, which show the result of observations on the east flank of the elevated ridge between Liebenburg and Gross-Doehren.

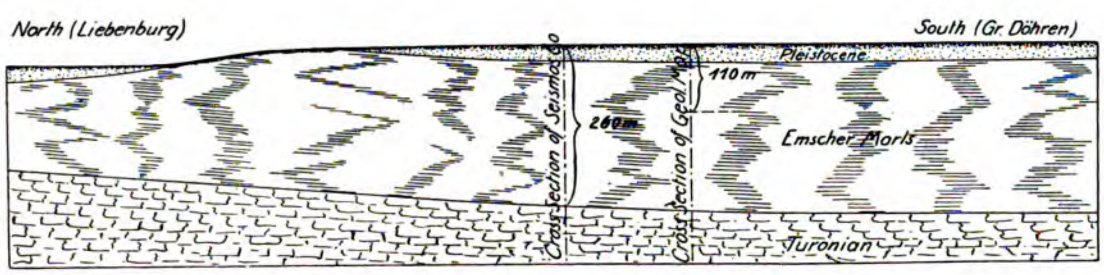

Fig. 18. Seismically determined longitudinal section at east flank of Salzgitter Hills.

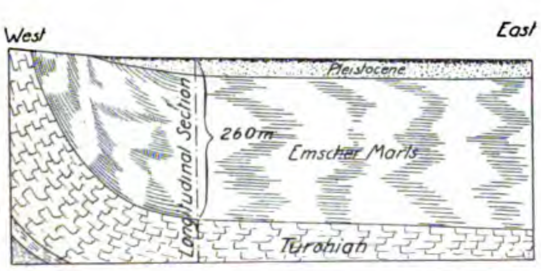

Fig. 19. Cross section, seismically determined.

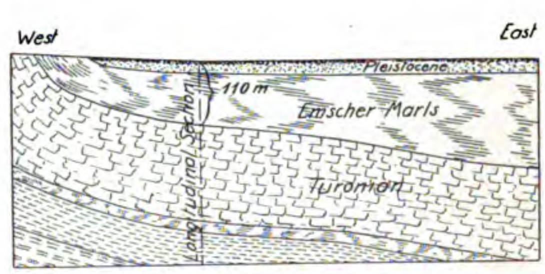

Fig. 20. Cross section according to geologic map.

At its intersection with the longitudinal section, the seismically determined cross section found 234 metres of Emscher Marls underneath a Pleistocene overburden of 26 metres. Compared with this, the cross section P-Q of the geological map (sheet Goslar) shows that the Turonian already begins at a depth of 110 metres.

The outcropping strata of the Turonian dip almost vertically, while, at a depth of 260 metres, they are only inclined 5° toward the east.

The seismically determined longitudinal section shows that the boundary face between the Emscher Marls and the Turonian rises gently toward the north, in the direction of Liebenburg. —

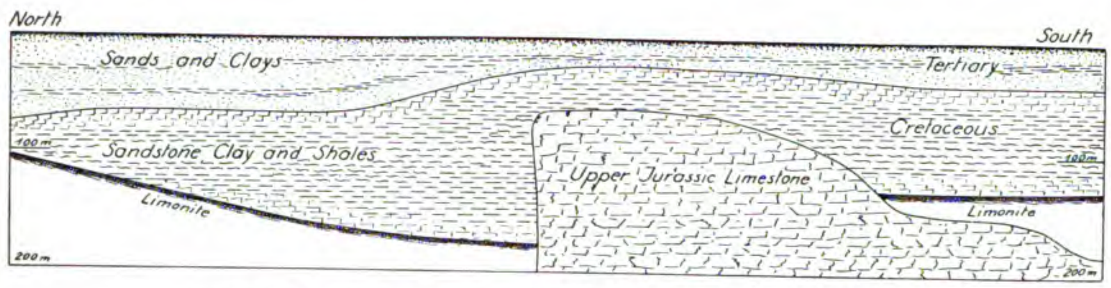

Fig. 21. Seismically determined section of the Jurassic of the Upper Palatinate.

Extended seismic observations for the determination of the structure of the subsurface and for the finding of ore-deposits were made in the Bavarian Upper Palatinate, for the Eisenwerk-Gesellschaft Maximilianshuette and for the Deutsch-Luxemburgische Bergwerks- und Huetten-Aktiengesellschaft. Figure 21 shows a section determined by seismic measurements. Underneath sand and clay of the Tertiary, and underneath "Veldenstein formations" of the Cretaceous, brown iron ore and spathic iron ore deposits occur. The occurrence of these is generally connected with the steps of the great rift zones of the Upper Palatinate Jurassic. The seismic observations determined these consecutive steps as well as the different formations and found the ore deposit.

Hannover, July 1922.